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(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Tire with Silica Reinforced Tread

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Abstract of the Disclosure

TIRE WITH SILICA REINFORCED TREAD

- 5        A pneumatic tire with a tread comprised of elastomer, silica, optionally carbon black, and a silica coupler comprised of dithiodipropionic acid.

TIRE WITH SILICA REINFORCED TREADField

5 This invention relates to tires reinforced with  
silica and particularly to tires with treads which are  
tires having rubber treads which are quantitatively  
reinforced with silica. In one aspect, the tread is  
comprised of rubber, particularly sulfur cured rubber,  
reinforced with a combination of silica and specified  
10 coupling agent and, optionally, carbon black.

Background

Pneumatic rubber tires are conventionally  
prepared with a rubber tread which can be a blend of  
15 various rubbers which is typically reinforced with  
carbon black.

In one aspect, rubbers are evaluated, selected  
and blended for a purpose of achieving desired tire  
tread properties and particularly a balance of tire  
20 tread characteristic properties, mainly, rolling  
resistance, traction and wear.

For various applications utilizing rubber which  
requires high strength and abrasion resistance,  
particularly applications such as tires and various  
25 industrial products, sulfur cured rubber is utilized  
which contains substantial amounts of reinforcing  
fillers. Carbon black is commonly used for such  
purpose and normally provides or enhances good  
physical properties for the sulfur cured rubber.  
30 Particulate silica is also often used for such  
purpose, particularly when the silica is used in  
conjunction with a coupling agent. In some cases, a  
combination of silica and carbon black is utilized for  
reinforcing fillers for various rubber products,  
35 including treads for tires.

It is important to appreciate that, conventionally, carbon black is a considerably more effective reinforcing filler for rubber products, and particularly for rubber tire treads than silica if the  
5 silica is used without a coupling agent, or silica coupler as it may be sometimes referred to herein.

Indeed, at least as compared to carbon black, there tends to be a lack of, or at least an insufficient degree of, physical and/or chemical  
10 bonding between the silica particles and the rubber elastomers to enable the silica to become a sufficient reinforcing filler for the rubber for most purposes, including tire treads, if the silica is used without a coupler. While various treatments and procedures have  
15 been devised to overcome such deficiencies compounds capable of reacting with both the silica surface and the rubber elastomer molecule, generally known to those skilled in such art as coupling agents, are often used. Such coupling agents may, for example, be  
20 premixed, or pre-reacted, with the silica particles or added to the rubber mix during the rubber/silica processing, or mixing, stage. If the coupling agent and silica are added separately to the rubber mix during the rubber/silica mixing, or processing stage,  
25 it is considered that the coupling agent then combines in situ with the silica.

In particular, such coupling agents are generally composed of a silane which has a constituent component, or moiety, (the silane portion) capable of  
30 reacting with the silica surface and, also, a constituent component, or moiety, capable of reacting with the rubber, particularly a sulfur vulcanizable rubber which contains carbon-to-carbon double bonds, or unsaturation. In this manner, then the coupler  
35 acts as a connecting bridge between the silica and the

rubber and thereby enhances the rubber reinforcement aspect of the silica.

5 In one aspect, the silane of the coupling agent apparently forms a bond to the silica surface, possibly through hydrolysis, and the rubber reactive component of the coupling agent combines with the rubber itself. Usually the rubber reactive component of the coupler is temperature sensitive and tends to combine with the rubber during the final and higher temperature sulfur vulcanization stage and, thus, subsequent to the rubber/silica/coupler mixing stage and, therefore, after the silane group of the coupler has combined with the silica. However, partly because of typical temperature sensitivity of the coupler, 10 some degree of combination, or bonding, may occur between the rubber-reactive component of the coupler and the rubber during an initial rubber/silica/coupler mixing stages and, thus, prior to a subsequent vulcanization stage.

20 The rubber-reactive group component of the coupler may be, for example, one or more of groups such as mercapto, amino, vinyl, epoxy, and sulfur groups, preferably a sulfur or mercapto moiety and more preferably sulfur.

25 Numerous coupling agents are taught for use in combining silica and rubber, such as, for example, silane coupling agents containing a polysulfide component, or structure, such as bis-(3-triethoxysilylpropyl)tetrasulfide and/or polyisoprene 30 rubber together with a mixture of silica and carbon black, with silica being required to be a major component of the silica/carbon black reinforcing filler.

35 Other U.S. patents relating to silicas and silica reinforced tire treads include U.S. Patents Nos.

3,451,458; 3,664,403; 3,768,537; 3,884,285; 3,938,574;  
4,482,663; 4,590,052; 5,089,554 and British 1,424,503.

U.S. Patent No. 4,513,123 discloses a rubber  
composition of dithiodipropionic acid with natural  
5 rubber, or blends of natural and synthetic rubbers,  
30-80 parts carbon black, sulfur and organo-cobalt  
compound for use as a skim coat for brass-plated  
steel. It relates that the rubber composition can  
contain other additives such as fillers such as clays,  
10 silicas or calcium carbonate, process and extender  
oils, antioxidants, cure accelerators, cure  
activators, cure stabilizers and the like.

#### Summary and Practice of the Invention

15 In accordance with this invention, a pneumatic  
tire is provided having a tread comprised of (A) 100  
parts by weight of at least one diene-based elastomer,  
(B) about 5 to about 90, optionally about 25 to about  
90, phr particulate silica, (C) about zero to about  
20 80, optionally up to about 30, phr carbon black, and  
(D) a silica coupler selected from (i)  
dithiodipropionic acid or from (ii) a combination of  
about 95 to about 25, preferably about 95 to about 55,  
weight percent dithiodipropionic acid and,  
25 correspondingly, about 5 to about 75, preferably about  
5 to about 45, weight percent bis-(3-  
triethoxysilylpropyl)tetrasulfide; wherein the weight  
ratio of said silica coupler to silica is in a range  
of about 0.01/1 to about 0.2/1; wherein the weight  
30 ratio of silica to carbon black, where said tread  
contains carbon black, is at least 0.1/1, optionally  
at least 3/1 and optionally at least 10/1; wherein the  
total of silica and carbon black, where said tread  
contains carbon black, is in a range of about 30 to  
35 about 120, more preferably about 45 to about 90.

Thus, in one aspect of the invention, the tread rubber contains a combination of both silica and carbon black as elastomer reinforcing pigments, although the tread rubber can contain silica as an exclusive reinforcing pigment.

Where the tread rubber composition contains both silica and carbon black pigments and it is desired that the tread be primarily reinforced with silica as the reinforcing pigment, it is preferable that the weight ratio of silica to carbon black, where carbon black is used, is at least 3/1, preferably at least 10/1 and preferably in a range of about 3/1 to about 30/1.

In one aspect of the invention, the silica coupler in the tire tread rubber composition consists essentially of the dithiodipropionic acid. While dithiodipropionic acid exists in isomer forms, such as the 3,3'- and 2,2'-forms, the 3,3'-dithiodipropionic acid form is preferred.

In one aspect, such a tire is provided with the tread being sulfur cured. The sulfur curing is accomplished in a conventional manner, namely by curing under conditions of elevated temperature and pressure for a suitable period of time.

In another aspect of the invention, it is contemplated, and indeed preferred, that the tread rubber composition is exclusive of any organo-cobalt compound.

The term "phr" as used herein, and according to conventional practice, refers to "parts of a respective material per 100 parts by weight of rubber, or elastomer".

In the description of this invention, the terms "rubber" and "elastomer" can be used interchangeably, unless otherwise distinguished. The terms "rubber composition", "compounded rubber" and "rubber

compound" can be used interchangeably to refer to rubber which has been blended or mixed with various ingredients and materials and such terms are well known to those having skill in the rubber mixing or rubber compounding art.

The dithiodipropionic acid may typically be characterized by having melting point in the range from 153°-159°C. Such melting point can conveniently be determined by a differential scanning calorimeter at a heating rate of 10°C/minute.

In the practice of this invention, as hereinbefore pointed out, the tread rubber composition is comprised of at least one diene-based elastomer, or rubber. Thus, it is considered that the elastomer is a sulfur curable elastomer. Such elastomer, or rubber, may be selected, for example, from at least one of cis 1,4-polyisoprene rubber (natural and/or synthetic, and preferably natural rubber), 3,4-polyisoprene rubber, styrene/butadiene copolymer rubbers, butadiene/acrylonitrile copolymer rubbers, styrene/isoprene/butadiene terpolymer rubbers, and cis 1,4-polybutadiene rubber.

In one aspect the rubber is preferably of at least two of diene based rubbers. For example a combination of two or more rubbers is preferred such as cis 1,4-polyisoprene rubber (natural or synthetic, although natural is preferred), 3,4-polyisoprene rubber, styrene/isoprene/butadiene rubber, emulsion and solution polymerization derived styrene/butadiene rubbers, cis 1,4-polybutadiene rubbers and emulsion polymerization prepared butadiene/acrylonitrile copolymers.

In one aspect of this invention, an emulsion polymerization derived styrene/butadiene (E-SBR) might be used having a relatively conventional styrene content of about 20 to about 28 percent bound styrene



or, for some applications, an E-SBR having a medium to relatively high bound styrene content, namely a bound styrene content of about 30 to about 45 percent.

5 The relatively high styrene content of about 30 to about 45 for the E-SBR can be considered beneficial for a purpose of enhancing traction, or skid resistance, of the tire tread. The presence of the E-SBR itself is considered beneficial for a purpose of enhancing processability of the uncured elastomer  
10 composition mixture, especially in comparison to a utilization of a solution polymerization prepared SBR (S-SBR).

By emulsion polymerization prepared E-SBR, it is meant that styrene and 1,3-butadiene are copolymerized  
15 as an aqueous emulsion. Such are well known to those skilled in such art. The bound styrene content can vary, for example, from about 5 to 50%. In one aspect, the E-SBR may also contain acrylonitrile to form a terpolymer rubber, as E-SBAR, in amounts, for  
20 example, of about 2 to about 30 weight percent bound acrylonitrile in the terpolymer.

Emulsion polymerization prepared butadiene/acrylonitrile copolymer rubbers containing about 2 to about 40 weight percent bound acrylonitrile  
25 in the copolymer are also contemplated as diene based rubbers for use in this invention.

The solution polymerization prepared SBR (S-SBR) typically has a bound styrene content in a range of about 5 to about 50, preferably about 9 to about 36,  
30 percent. The S-SBR can be conveniently prepared, for example, by organo lithium catalyzation in the presence of an organic hydrocarbon solvent.

A purpose of using S-SBR is for improved tire rolling resistance as a result of lower hysteresis  
35 when it is used in a tire tread composition.

The 3,4-polyisoprene rubber (3,4-PI) is considered beneficial for a purpose of enhancing the tire's traction when it is used in a tire tread composition.

5       The 3,4-PI and use thereof is more fully described in U.S. Patent No. 5,087,668 which is incorporated herein by reference. The Tg refers to the glass transition temperature which can conveniently be determined by a differential scanning  
10       calorimeter at a heating rate of 10°C per minute.

The cis 1,4-polybutadiene rubber (BR) is considered to be beneficial for a purpose of enhancing the tire tread's wear, or treadwear.

15       Such BR can be prepared, for example, by organic solution polymerization of 1,3-butadiene.

The BR may be conveniently characterized, for example, by having at least a 90% cis 1,4-content.

20       The cis 1,4-polyisoprene and cis 1,4-polyisoprene natural rubber are well known to those having skill in the rubber art.

25       The vulcanized rubber tread should contain a sufficient amount of silica, and carbon black if used, as reinforcing filler(s) to contribute a reasonably high modulus and high resistance to tear. The combined weight of the silica and carbon black, as hereinbefore referenced, may be as low as about 30 parts per 100 parts rubber, but is preferably from about 45 to about 90 parts by weight.

30       The commonly employed siliceous pigments used in rubber compounding applications can be used as the silica in this invention, including pyrogenic and precipitated siliceous pigments (silica), although precipitate silicas are preferred.

35       The siliceous pigments preferably employed in this invention are precipitated silicas such as, for

example, those obtained by the acidification of a soluble silicate, e.g., sodium silicate.

Such silicas might be characterized, for example, by having a BET surface area, as measured using  
5 nitrogen gas, preferably in the range of about 40 to about 600, and more usually in a range of about 50 to about 300 square meters per gram. The BET method of measuring surface area is described in the Journal of the American Chemical Society, Volume 60, page 304  
10 (1930).

The silica may also be typically characterized by having a dibutylphthalate (DBP) absorption value in a range of about 100 to about 400, and more usually about 150 to about 300.

15 The silica might be expected to have an average ultimate particle size, for example, in the range of 0.01 to 0.05 micron as determined by the electron microscope, although the silica particles may be even smaller, or possibly larger, in size.

20 Various commercially available silicas may be considered for use in this invention such as, only for example herein, and without limitation, silicas commercially available from PPG Industries under the Hi-Sil trademark with designations 210, 243, etc;  
25 silicas available from Rhone-Poulenc, with, for example, designations of Z1165MP and Z165GR, silicas available from Degussa AG with, for example, designations VN2 and VN3, and silicas from Akzo Chemical, etc. The PPG Hi-Sil silicas are currently  
30 preferred.

It is readily understood by those having skill in the art that the rubber composition and the rubber composition of the tread rubber would be compounded by methods generally known in the rubber compounding art,  
35 such as mixing the various sulfur-vulcanizable constituent rubbers with various commonly used

additive materials such as, for example, curing aids, such as sulfur, activators, retarders and accelerators, processing additives, such as oils, resins including tackifying resins, silicas, and  
5 plasticizers, fillers, pigments, fatty acid, zinc oxide, waxes, antioxidants and antiozonants, peptizing agents and reinforcing materials such as, for example, carbon black. As known to those skilled in the art, depending on the intended use of the sulfur  
10 vulcanizable and sulfur vulcanized material (rubbers), the additives mentioned above are selected and commonly used in conventional amounts.

Typical amounts of reinforcing type carbon blacks(s), for this invention, if used, are  
15 hereinbefore set forth. It is to be appreciated that the silica coupler may be used in conjunction with a carbon black, namely pre-mixed with a carbon black prior to addition to the rubber composition, and such carbon black is to be included in the aforesaid amount  
20 of carbon black for the rubber composition formulation. Typical amounts of tackifier resins, if used, comprise about 0.5 to about 10 phr, usually about 1 to about 5 phr. Typical amounts of processing aids comprise about 1 to about 50 phr. Such  
25 processing aids can include, for example, aromatic, naphthenic, and/or paraffinic processing oils. Typical amounts of antioxidants comprise about 1 to about 5 phr. Representative antioxidants may be, for example, diphenyl-p-phenylenediamine and others, such as, for  
30 example, those disclosed in the Vanderbilt Rubber Handbook (1978), pages 344-346. Typical amounts of antiozonants comprise about 1 to 5 phr. Typical amounts of fatty acids, if used, which can include stearic acid comprise about 0.5 to about 3 phr.  
35 Typical amounts of zinc oxide comprise about 2 to about 5 phr. Typical amounts of waxes comprise about

1 to about 5 phr. Often microcrystalline waxes are used. Typical amounts of peptizers comprise about 0.1 to about 1 phr. Typical peptizers may be, for example, pentachlorothiophenol and dibenzamidodiphenyl disulfide.

The vulcanization is conducted in the presence of a sulfur vulcanizing agent. Examples of suitable sulfur vulcanizing agents include elemental sulfur (free sulfur) or sulfur donating vulcanizing agents, for example, an amine disulfide, polymeric polysulfide or sulfur olefin adducts. Preferably, the sulfur vulcanizing agent is elemental sulfur. As known to those skilled in the art, sulfur vulcanizing agents are used in an amount ranging from about 0.5 to about 4 phr, or even, in some circumstances, up to about 8 phr, with a range of from about 1.5 to about 2.5, sometimes from 2 to 2.5, being preferred.

Accelerators are used to control the time and/or temperature required for vulcanization and to improve the properties of the vulcanizate. In one embodiment, a single accelerator system may be used, i.e., primary accelerator. Conventionally and preferably, a primary accelerator(s) is used in total amounts ranging from about 0.5 to about 4, preferably about 0.8 to about 1.5, phr. In another embodiment, combinations of a primary and a secondary accelerator might be used with the secondary accelerator being used in smaller amounts (of about 0.05 to about 3 phr) in order to activate and to improve the properties of the vulcanizate. Combinations of these accelerators might be expected to produce a synergistic effect on the final properties and are somewhat better than those produced by use of either accelerator alone. In addition, delayed action accelerators may be used which are not affected by normal processing temperatures but produce a satisfactory cure at

ordinary vulcanization temperatures. Vulcanization retarders might also be used. Suitable types of accelerators that may be used in the present invention are amines, disulfides, guanidines, thioureas, thiazoles, thiurams, sulfenamides, dithiocarbamates and xanthates. Preferably, the primary accelerator is a sulfenamide. If a second accelerator is used, the secondary accelerator is preferably a guanidine, dithiocarbamate or thiuram compound. The presence and relative amounts of sulfur vulcanizing agent and accelerator(s) are not considered to be an aspect of this invention which is more primarily directed to the use of silica as a reinforcing filler in combination with dithiodipropionic acid as a coupling agent. The presence and relative amounts of the above additives are not considered to be an aspect of the present invention which is more primarily directed to the utilization of specified blends of rubbers in tire treads, in combination with silica and dithiodipropionic acid, or blends of dithiodipropionic acid and bis-(3-triethoxysilylpropyl)tetrasulfide as well as, optionally, carbon black, for the reinforcement of the rubber.

The mixing of the rubber composition can be accomplished by methods known to those having skill in the rubber mixing art. For example the ingredients are typically mixed in at least two stages, namely at least one non-productive stage followed by a productive mix stage. The final curatives are typically mixed in the final stage which is conventionally called the "productive" mix stage in which the mixing typically occurs at a temperature, or ultimate temperature, lower than the mix temperature(s) than the preceding non-productive mix stage(s). The rubber, silica and silica coupler, and carbon black if used, are mixed in one or more non-

productive mix stages. The terms "non-productive" and "productive" mix stages are well known to those having skill in the rubber mixing art.

5 The tire can be built, shaped, molded and cured by various methods which are known and will be readily apparent to those having skill in such art.

The invention may be better understood by reference to the following examples in which the parts and percentages are by weight unless otherwise  
10 indicated.

EXAMPLE I

In this example, 3,3'-dithiodipropionic acid is  
15 evaluated as an alternative for a commonly used silica coupling agent, bis-(3-triethoxysilylpropyl) tetrasulfide, in a silica reinforced rubber composition. Rubber compositions containing the materials set out in Tables 1 and 2 were prepared in a  
20 BR Banbury mixer using three separate stages of addition (mixing), namely, two non-productive mix stages and one productive mix stage to temperatures of 160°C, 160°C and 120°C and times of 4 minutes, 4 minutes and 2 minutes, respectively. The amount of  
25 coupler is listed as being "variable" in Table 1 and is more specifically set forth in Table 2.

The rubber compositions are identified herein as Samples X, Y and Z, with Samples Y and Z utilizing the silica couplers, respectively, and Sample X considered  
30 herein as being a control without the use of a silica coupler.

The Samples were cured at about 150°C for about 36 minutes.

Table 2 illustrates the behavior and physical  
35 properties of the cured Samples X, Y and Z.

It is clearly evident from the results that a coupling agent is required (Samples Y and Z) to obtain suitable cured properties in a silica containing rubber compound. Such properties include tensile  
5 strength at break, the 100 and 300% modulus values, rebound, hardness and Rheovibron E' and tan delta values.

The dithiodipropionic acid used as a silica coupler (Sample Z) is observed to provide larger  
10 improvements in these properties than a conventional bis-(3-triethoxysilylpropyl)tetrasulfide silica coupling agent (Sample Y).

This is considered an advantage because it is shown that rubber properties equivalent to the silane  
15 coupler might be achieved with less dithiodipropionic acid and potential lower cost. Thus, the dithiodipropionic acid is considered herein to be a suitable alternative for bis-(3-triethoxysilylpropyl)tetrasulfide as a silica coupling agent in a silica  
20 reinforced rubber composition.



Table 1	
<u>1st Non-Productive</u>	
Natural Rubber <sup>1</sup>	100.00
Carbon Black	35.00
Processing Oil	5.00
Zinc Oxide	5.00
Fatty Acid	2.00
Antioxidant <sup>2</sup>	2.00
<u>2nd Non-Productive</u>	
Silica <sup>3</sup>	15.00
Bis- (3-triethoxysilylpropyl) tetrasulfide <sup>4</sup>	variable
3,3'-Dithiodipropionic Acid	variable
<u>Productive</u>	
Sulfur	1.40
Accelerator, sulfenamide type	1.00

1) natural rubber (cis 1,4-polyisoprene);

2) of the polymerized 1,2-dihydro-2,2,4-trimethyldihydroquinoline type;

3) Silica obtained as Hi-Sil-210 from PPG Industries, Inc.;

4) obtained as bis-(3-triethoxysilylpropyl)tetrasulfide, commercially available as Si69 from Degussa

GmbH which is provided in a 50/50 blend with carbon black and, thus, considered as being 50% active when the blend is considered.

5	<b>Table 2</b>			
	<u>Sample #</u>	<u>X</u>	<u>Y</u>	<u>Z</u>
10	Bis-(3-triethoxysilylpropyl) tetrasulfide (50% active)	0	3.0	0
	3,3'-Dithiodipropionic Acid	0	0	1.5
	<u>Rheometer (150°C)</u>			
	Max. Torque	30.8	35.6	40.7
15	Min. Torque	7.0	6.4	7.0
	Delta Torque	23.8	29.2	33.7
	T <sub>90</sub> , minutes	23.0	19.5	28.0
	T <sub>25</sub> , minutes	17.3	13.3	14.5
	<u>Stress-Strain</u>			
20	Tensile Strength, MPa	15.8	18.8	20.4
	Elongation at Break, %	635	574	551
	100% Modulus, MPa	1.11	1.76	2.26
	300% Modulus, MPa	4.89	8.35	9.65
	<u>Rebound</u>			
25	100°C, %	46.8	54.6	60.3
	<u>Hardness</u>			
	100°C	55.3	59.6	61.5
	<u>Rheovibron</u>			
	E' at 60°C, MPa	10.1	13.0	17.6
30	Tan Delta at 60°C	.106	.103	.071

EXAMPLE II

Rubber compositions, identified herein as Sample  
5 A and Sample B, containing the materials shown in  
Table 3 were prepared in a BR Banbury mixer using four  
separate stages of addition, namely, three successive  
non-productive mix stages followed by a productive mix  
stage to temperatures of 160°C, 160°C, 160°C and 120°C  
10 and times of 4, 4, 4, and 2 minutes, respectively.

The Samples contained 80 parts silica and 5 parts  
carbon black.

The Samples were cured at a temperature of about  
150°C for about 36 minutes.

15 Sample A is considered a control without a silica  
coupler and Sample B utilizes dithiodipropionic acid  
as a silica coupler.

Table 4 shows the cure behavior and physical  
properties of the cured Samples.

20 It is clearly evident that the rubber composition  
(compound) containing the dithiodipropionic acid  
silica coupler (Sample B) generated a much higher  
delta torque and also that it had a much higher Shore  
A hardness.

25 This is considered an advantage because higher  
rubber stiffness can be achieved with relatively equal  
amounts of dithiodipropionic acid or the  
tetrasulfide/silane coupler or relatively equal  
stiffness can be achieved at lower dithiodipropionic  
30 acid levels than the tetrasulfide/silane coupler.

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Table 3		
<u>1st Non-Productive</u>	<u>Sample A</u>	<u>Sample B</u>
Natural Rubber	100.0	100.0
Silica	45.0	45.0
Dithiodipropionic Acid	0	4.0
Zinc Oxide	5.0	5.0
Fatty Acid	4.0	4.0
Zinc Carbonate	3.0	3.0
Carbon Black	5.0	5.0
Antioxidant	2.0	2.0
<u>2nd Non-Productive</u>		
Silica	20.0	20.0
Zinc Carbonate	1.0	1.0
Processing Oil	5.0	5.0
<u>3rd Non-Productive</u>		
Silica	15.0	15.0
Processing Oil	5.0	5.0
<u>Productive</u>		
Sulfur	1.5	1.5
Accelerators, of the sulfenamide and guanidine type	3.5	3.5

Table 4		
	Sample A	Sample B
3,3'-Dithiodipropionic Acid	0	4.0
<u>Rheometer (150°C)</u>		
Max. Torque	45.8	47.8
Min. Torque	25.2	14.0
Delta Torque	20.6	33.8
T <sub>90</sub> , minutes	24.4	30.0
T <sub>25</sub> , minutes	13.9	23.5
<u>Shore A Hardness</u>		
Room Temperature	69	78

### EXAMPLE III

In this example, a combination of both bis-(3-triethoxysilylpropyl)tetrasulfide and dithiodipropionic acid are used as coupling agents in a rubber compound containing silica and carbon black (Table 5).

The rubber compositions are referred to herein as Sample C as a control using the dithiodipropionic acid as the silica coupler and Sample D using both the dithiodipropionic acid and the bis-(3-triethoxysilylpropyl)tetrasulfide as a combination of silica couplers.

The rubber compositions were prepared by mixing the ingredients in two non-productive and one productive mix stage to temperatures of about 160°C,

160°C and 120°C and times of about 4, 4, and 2 minutes, respectively.

The Samples were cured at a temperature of about 150°C for about 36 minutes.

5       Cure behavior and cured properties for Sample C and Sample D are shown in Table 6. The combination of silica couplers is observed to provide higher stiffness in cured rubber properties and also lower minimum torque for the compounded rubber by the  
10       Monsanto rheometer test. The lower minimum torque for the combination of silica couplers, Sample D, verses the compound (rubber composition) containing dithiodipropionic acid, Sample C, suggests the combination might provide better processing as a  
15       result of lower compound viscosity.

      Thus, the combination of dithiodipropionic acid/tetrasulfide-silane couplers may be considered an advantage in some situations because of improved processing during calendering milling or extrusion of  
20       the rubber composition because of a lower rubber composition viscosity.

Table 5	
<u>1st Non-Productive</u>	
5	Natural Rubber 100.00
	Carbon Black 35.00
	Processing Oil 5.00
	Zinc Oxide 5.00
	Fatty Acid 2.00
	Antioxidant 2.00
10	<u>2nd Non-Productive</u>
	Silica 15.00
	bis-(3-triethoxysilyl-propyl)tetrasulfide (50 % active) 0 or 3.0
15	Dithiodipropionic Acid 0 or 1.0
	<u>Productive</u>
	Sulfur 1.40
20	Accelerator of the Sulfenamide type 1.0

Table 6			
	Sample #	C	D
5	bis- (3-triethoxysilyl- propyl)tetrasulfide (50 % active)	0	3.0
	3,3'-Dithiodipropionic Acid	1.0	1.0
<u>Rheometer (150°C)</u>			
10	Max. Torque	42.7	43.3
	Min. Torque	8.0	7.0
	Delta Torque	34.7	36.3
	T <sub>90</sub> , minutes	24.5	25.5
<u>Stress-Strain</u>			
15	Tensile Strength, MPa	21.0	22.1
	Elongation at Break, %	555	555
	100% Modulus, MPa	2.23	2.46
	300% Modulus, MPa	9.78	11.06
<u>Rebound</u>			
20	100°C, %	63.4	62.0
<u>Hardness</u>			
	100°C	58.6	60.3
<u>Rheovibron</u>			
	E' at 60°C, MPa	17.2	19.3
25	Tan Delta at 60°C	.064	.071



EXAMPLE IV

5       Pneumatic rubber tires are prepared as steel  
belted radial ply tires, which have sulfur cured  
rubber treads of this invention.

10       While certain representative embodiments and  
details have been shown for the purpose of  
illustrating the invention, it will be apparent to  
those skilled in this art that various changes and  
modifications may be made therein without departing  
from the spirit or scope of the invention.

WHAT IS CLAIMED IS:

1. A pneumatic tire having a tread comprised  
of (A) 100 parts by weight of at least one diene-based  
5 elastomer, (B) about 5 to about 90 phr particulate  
silica, (C) about zero to about 80 phr carbon black,  
and (D) a silica coupler selected from (i)  
dithiodipropionic acid or from (ii) about 95 to about  
25 weight percent dithiodipropionic acid and,  
10 correspondingly, about 5 to about 75 weight percent  
bis-(3-triethoxysilylpropyl)tetrasulfide; wherein the  
weight ratio of said silica coupler to silica is in a  
range of about 0.01/1 to about 0.2/1; wherein the  
weight ratio of silica to carbon black, if the tread  
15 contains carbon black, is at least about 0.1/1 and  
where the total of silica and carbon black, if the  
tread contains carbon black, is in a range of about 30  
to about 120.
- 20 2. The tire of claim 1 wherein, for the tire  
tread, the silica coupler consists essentially of  
dithiodipropionic acid.
3. The tire of claim 1 wherein, for the tire  
25 tread, the silica coupler consists essentially of  
3,3'-dithiodipropionic acid.
4. The tire of claim 1 wherein, in the tire  
tread, the silica coupler is a combination of about 95  
30 to about 25 weight percent dithiodipropionic acid and,  
correspondingly, about 5 to about 75 weight percent  
bis-(3-triethoxysilylpropyl)tetrasulfide.
5. The tire of claim 4 where said  
35 dithiodipropionic acid is 3,3'-dithiodipropionic acid.

6. The tire of claim 1 wherein, in the tire tread, the diene based elastomer is selected from at least one of cis 1,4-polyisoprene rubber, 3,4-polyisoprene rubber, styrene/butadiene copolymer rubbers, styrene/isoprene/butadiene terpolymer rubbers, cis 1,4-polybutadiene rubber, and emulsion polymerization prepared styrene/butadiene/acrylonitrile terpolymer rubber and butadiene/acrylonitrile copolymer rubber.
7. The tire of claim 3, wherein, for the tire tread, the elastomer is at least two diene based rubbers selected from at least two of cis 1,4-polyisoprene natural rubber, 3,4-polyisoprene rubber, styrene/isoprene/butadiene rubber, emulsion and solution polymerization derived styrene/butadiene rubbers and cis 1,4-polybutadiene rubbers.
8. The tire of claim 4, wherein, in the tire tread, the diene based elastomer is selected from at least one of cis 1,4-polyisoprene rubber, 3,4-polyisoprene rubber, styrene/butadiene copolymer rubbers, styrene/isoprene/butadiene terpolymer rubbers, cis 1,4-polybutadiene rubber, and emulsion polymerization prepared styrene/butadiene/acrylonitrile terpolymer rubber and butadiene/acrylonitrile copolymer rubber.
9. The tire of claim 5, wherein, for the tire tread, the elastomer is at least two diene based rubbers selected from at least two of cis 1,4-polyisoprene natural rubber, 3,4-polyisoprene rubber, styrene/isoprene/butadiene rubber, emulsion and solution polymerization derived styrene/butadiene rubbers cis 1,4-polybutadiene rubbers, and emulsion polymerization prepared styrene/butadiene/

acrylonitrile terpolymer rubber and  
butadiene/acrylonitrile copolymer rubber.

10. The tire of claim 7, wherein, for the tire  
5 tread, the emulsion polymerization styrene/butadiene  
(E-SBR) has a bound styrene content in a range of  
about 30 to about 45 percent.

11. The tire of claim 9, wherein, for the tire  
10 tread, the emulsion polymerization styrene/butadiene  
(E-SBR) has a bound styrene content in a range of  
about 30 to about 45 percent.

12. The tire of claim 1 wherein, for the tread,  
15 the silica is characterized by having a BET surface  
area in a range of about 50 to about 300 square meters  
per gram and a dibutylphthalate (DBP) absorption value  
in a range of about 150 to about 300; and where the  
tread is exclusive of any organo-cobalt compound.

13. The tire of claim 3 wherein, for the tread,  
the silica is characterized by having a BET surface  
area in a range of about 50 to about 300 square meters  
per gram and a dibutylphthalate (DBP) absorption value  
25 in a range of about 150 to about 300; and where the  
tread is exclusive of any organo-cobalt compound.

14. The tire of claim 4 wherein, for the tread,  
the silica is characterized by having a BET surface  
30 area in a range of about 50 to about 300 square meters  
per gram and a dibutylphthalate (DBP) absorption value  
in a range of about 150 to about 300; and where the  
tread is exclusive of any organo-cobalt compound.

15. The tire of claim 7 wherein, for the tread,  
35 the silica is characterized by having a BET surface

area in a range of about 50 to about 300 square meters per gram and a dibutylphthalate (DBP) absorption value in a range of about 150 to about 300; and where the tread is exclusive of any organo-cobalt compound.

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16. A pneumatic tire having a tread comprised of (A) 100 parts by weight of at least one diene-based elastomer, (B) about 25 to about 90 phr particulate silica, (C) up to about 30 phr carbon black, and (D) a silica coupler selected from (i) 3,3-dithiodipropionic acid or from (ii) about 95 to about 55 weight percent 3,3-dithiodipropionic acid and, correspondingly, about 5 to about 45 weight percent bis-(3-triethoxysilylpropyl)tetrasulfide; wherein the weight ratio of said silica coupler to silica is in a range of about 0.01/1 to about 0.2/1; wherein the weight ratio of silica to carbon black is in a range of about 3/1 to about 30/1; wherein the total of silica and carbon black is in a range of about 30 to about 120; wherein the silica is characterized by having a BET surface area in a range of about 50 to about 300 square meters per gram and a dibutylphthalate (DBP) absorption value in a range of about 150 to about 300; and wherein the tread is exclusive of any organo-cobalt compound.

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